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Identification and Mitigation of Difficulties in Hydro-Power Generation in Tripura using MCDM and Cost Effective Analysis

Dr. Mrinmoy Majumder* Shirsendu Das and Tilottama Chakraborty

National Institute of Technology Agartala, Jirania

Abstract

In 21th centaury energy has become a prime need of the civilization. One of the most important types of energy is the electrical energy, which is very much essential for both domestic & industrial purposes. In present century, more than 60% of the total electric energy is producing from coals, 14-17% of energy is producing from Renewable sources & the remaining part is from natural gases. So, it is clear that maximum sources (more than 80%) of energy are causes pollution. Pollution & Global warming are the main reason of rapid environmental misbalancing. In case of our state (Tripura) this energy generation figures or records are not impressive, approximately 1% of total energy is producing from hydro-power & the rest percentages are from gas-thermal plants. It is observed that the year round insufficiencies of river water & irregular rainfall in hilly river sub-basin areas are the main reasons of decrement in hydro-power generation. So, in present scenario, the concept of Pump-Storage Hydro-Power station is very much appropriate, because this type of plant can recycle fix storage of water. That's why insufficiency of river water will not affect the generation like conventional hydro power station. In this work Multi Criteria Decision Making Algorithm (MCDMA) is used to find the best alternative with respect to the design consideration to select a best location in this state to set pump storage plant, the suitable location has been selected by both MCDM (AHP) & cost effective analysis. This work tried to give some key point regarding the problems, mitigations & future scope of Gomati Hydro Power Project by integrated studies on Dumbur Lake, river sub-basin, average annual rainfall & annual mean depth of the river. At the end the project implies a probability of more than 11 MW Hydro-power generations by installing Mini-Hydro Pump storage plant in this state Tripura using the water of River Gomati. Finally plant network has been optimized by Flex-Sim software, to check the efficiencies of different component under the assigned/ proposed conditions.

Keywords: *Scattering of Dumboor Lake, MCDM, AHP, Cost effective study, Network optimization*

1. Introduction

Tripura's sole hydro station Gomati hydro project is almost in dead condition with approximate generation of 2-4 MW. The plant started in 1976 with installation capacity of 15 MW. A dam is there on west Kalajhari hill which store water in a lake near Tirthamukh named Dunboor. The lake provides the kinetic as well as potential head to the plant. Three turbines, with 5 MW each were installed in it. But at present only one unit is running from these three. One of the rests two is presently in damage condition due to improper observation & the other one are stopped due to insufficient water storage. The average annual power output for last 10 years is represented bellow:

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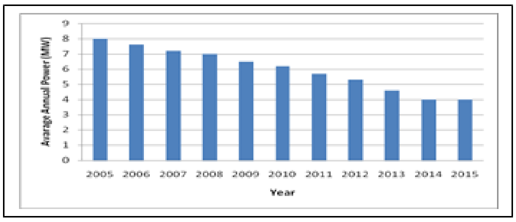


2. Reasons behind the Decrease in Generation

There are so many reasons behind the decreasing rate of generation of Gomati Hydro-Power project. But among these reasons, two reasons are most effective and important. They are:

a. Scattering of Dumboor Lake: Dam should prepare in such a location so that it can store & hold the water just behind it. The geography of nearby location should be such so that it can help to store the water. The nearby area should prevent the run off of water behind the dam so that whole kinetic & potential head can apply in power generation. Just like the bellow mentioned figures:

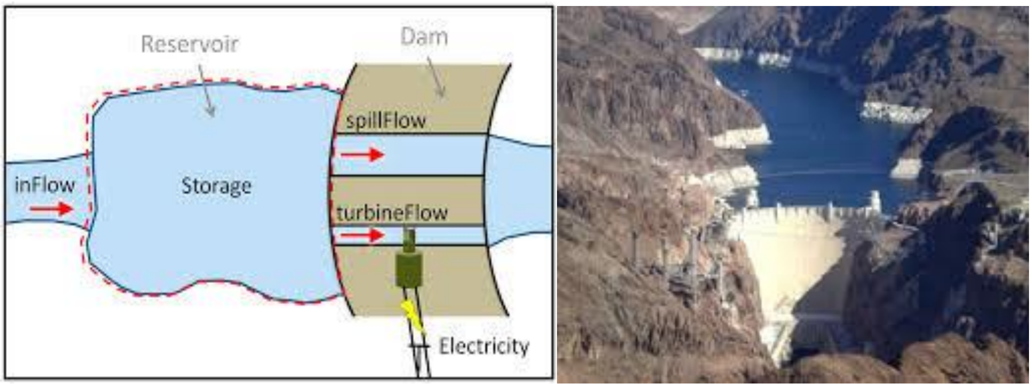


Figure 2 a & 2 b. (Actual Storage Nature Behind Dam for High Generating Plant)

But, in case of dumboor, this type of storage is not possible. Area of the lake is scattering & it is deflecting from the main stream of river.

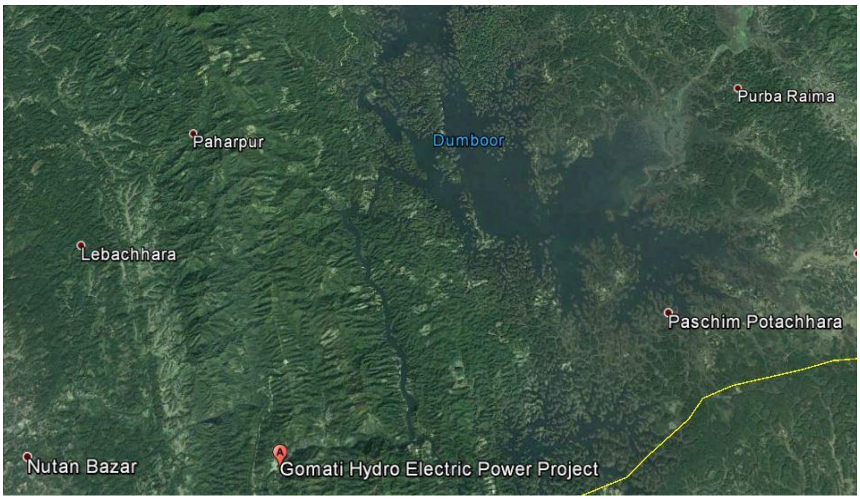


Figure 2c. (Gomati Hydro Project & Dumboor Lake)

Due to its wide range (with compare to the water flow rate of river Gomati) it can't develop sufficient head of storage water behind the dam for power generation; moreover the back flow of water from the lake has become the cause of flood in nearby locality. Presently (February 2015) the Storage Lake has no contribution in power generation but it hold a large quantity of river water so the downstream river has become almost dry in some areas. So with the gradual reduction of rainfall the quantity of water behind the dam is decreasing & lake is becoming a dying lake.

B. Decrement of Annual Rainfall: At the beginning or before 2000 (near 1996) when the hydro project capable to produce more than 8 MW, the sub-basin of the river received annual rainfall of 2238.40 mm. But in 2009, it is bellow 1500 m (1420 mm approx) again in 2009 it increased up to near 2000 mm but in 2010 or onward it is decreasing & in 2013 it decreased up to 1400 mm.

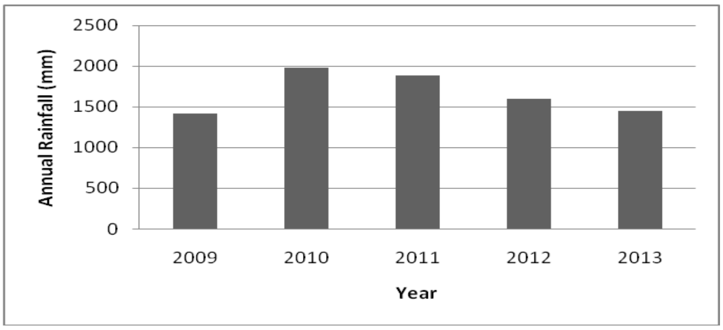


Figure 7.4. (Annual Rainfall with Time)

The average water level of the river in the downstream side was maximum in 2007, it was 9.24 m & minimum in 2009 approximately 8.61 m. In 2010 it slightly increased near 8.83 m but after that it is decreasing subsequently & in 2014 it was near 8.64 m.

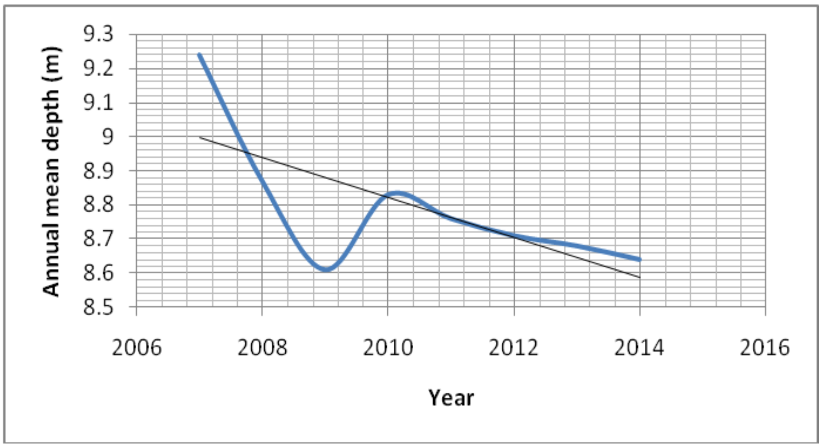


Figure 2d. (Average Mean Depth Variation with Time)

The gradual decrement in the annual mean depth implies that there is regularly reduction in rainfall in the Gomati sub-basin & the rainfall bar-chart and the rainfall records which are mentioned also implies the same thing. If this type of natural calamities are continued then few years after the only hydro-power station of Tripura will stops its generation.

3. Mitigations & Alternative Options

Plantation in The Gomati Sub-Basin: It is observed that due to increased numbers of localization in the hilly areas adjacent to the river basin, there is a gradual reduction in green plants due to deforestation. So more plantation is required in hilly area, this will increase the average rainfall at the hilly areas & effects directly in the generation of the plant.

Set Up Pump Storage Micro Hydro Plant As Substation: The present status of river Gomati & its related natural condition is not fit for satisfactory scale of hydro power generation. As pump storage plant can operate with a fixed volume of water then a plant may set to mitigate the hydro power (green energy) demand of the state.

4. Site selection for Pump Storage Plant in Tripura

The state Tripura has many locations which are suitable for small hydro-power generation due to geographically hilly lands & river streams. Among of these places two best places have been taken due to their favorable geographical location, easy reachable facilities & transportation connectivity. The details of the following two places have been given bellow:

Location 1. (Kalajhari Hill near Dombur Hydro-Power Plant)

Available head	70 m to 100 m head is available to set upper reservoir.
Slop of the hill	For 100 m height the elevation is 290 m (approx)
Distance of nearest locality from the generating station	Nearby locality is 4.6 Km (approx) away from generating station.
Possibilities of upper reservoir construction	Cost effective analysis is required.
River available	Gomati River

Location 2. (Atharomura Hill)	
Available head	70 m to 100 m head is available to set upper reservoir.
Slop of the hill	For 100 m height the elevation is 375 m (approx)
Distance of nearest locality from the generating station	Nearby locality is 7 Km (approx) away from generating station.
Possibilities of upper reservoir construction	Cost effective analysis is required.
River available	Raima river

Multi Criteria Decision Making Process (MCDM): 'MCDM' is a decision making process where more than one criteria are present and the main objective is to select the best criteria with respect to more than one alternatives. Analytical Hierarchy Process (AHP) is a MCDM which is used to find the best criteria among the mentioned four criteria of location selection or rank the criteria with respect to four alternatives i.e design factors.

Selection criteria:

To select a location for pump storage plant the following criterias are important:

a. Available head.

b. Available slope.
c. Possibilities of upper reservoir construction.
d. Distance of the nearest distributing area from the generating station.

Some considerable design factors:

a. Efficiency of the plant.
b. Cost required.
c. Design condition.
d. Various losses associated with the plant.

Now 'AHP' is used to give wattage to the factors & select the best criteria among the above listed criterias.

Importance of the Design Factors:

In maximum literature reviews, more importance is given to the design conditions, because if the selected place is not good in design aspects then design cost, installation cost etc will be more. On the other hand if the place is not suitable for design then the assigned plant output & efficiency both will not be up to the mark. So proper & suitable design condition is most important factor for PSP set up.

Out of rest three factors the efficiency is most important one, because for any plant efficiency the prime requirement which indicate the correlation between the input energy & output energy. Again if the efficiency is less the cost will increase, now for the rest two parameters 'loss' is more important, because if 'loss' increase both the efficiency & cost will increase.

Design condition (D) > Plant efficiency (E) > required cost (C) > Losses (L)

Factors with importance
Design condition is two (2) time important than plant efficiency.
Plant efficiency is three (3) times important than cost required.
Design condition is four (4) times important than losses.
Plant is five (5) times important than losses.

	D	E	C	L
D	1	1/4	1/3	6/1
E	4/1	1	2/1	7/1
C	3/1	1/2	1	5/1
L	1/6	1/7	1/5	1

Table 3.1. (Arrangement of Factors According To Importance)

1.89	0.232	
3.5	0.430	Maximum wattage is given to efficiency.
2.37	0.291	
0.377	0.046	Minimum wattage is given to losses
Total = 8.137	After normalizing	

With respect to the importance of these alternatives wattage have been given. But these are not actual wattage. Final wattage will come after the development of final matrix considering the various design alternatives. Step of final matrix formation has been given bellow.

Importance of Criteria W.R.T Design Condition:

Head, slope, reservoir construction & distance of nearest locally are the most important criteria for PSP set up. In case of any selected place if the geographical condition is suitable for dam construction & natural slopes is available than design hurdles will reduce. So, w.r.t design these two criteria are most important. Among these two criteria possibilities of upper reservoir construction is most important because without the upper reservoir generation is not possible. The rest two criteria i.e head & distance of locality are not directly related with design condition. But if the distance is more cost will increase that's why distance of nearby locality is the third preference.

Importance Of Criteria's With Respect To Design Condition				
Possibilities of reservoir construction is two (2) times important than slope.				
Slope is three (3) times important than distance.				
Possibilities of reservoir construction is four (4) times important than distance.				
Slope is five (5) times important than head.				
Distance of the nearest locality is six (6) times important than head.				
Possibilities of reservoir construction is seven (7) times important than head.				
	Head	Slope	Distance	Possibilities of reservoir construction
Head	1	1/5	1/6	1/7
Slope	5/1	1	3/1	½
Distance	6/1	1/3	1	¼
Possibilities of reservoir construction	7/1	2/1	4/1	1

Table 3.2. (Arrangement of Criteria with Their Importance, W.R.T Design)

0.3773	0.0430
2.375	0.2915
1.895	0.2325
3.5	0.4295
Total = 8.1473	After normalizing

Importance With Respect To Efficiency:

For a fixed quantity of input if output can maximize efficiency also increase. Head & slop of plant is very much related to the plant output. It is very much clear that the hydro-power output is proportional to the head. If head is increased output as well as efficiency also increases. On the other side if the inclination of plant alignment is more i.e. the penstock length is less so the head losses due to friction are less. If losses can minimize efficiency will maximize, so the slop of the location is the second important criteria, rest two criteria have no direct influence on efficiency, so with respect to cost last two criteria have been ranked.

Importance of criterias with respect to efficiency				
Head is two (2) times important than slope.				
Slope is three (3) times important than distance.				
Head is four (4) times important than distance.				
Slope is five (5) times important than possibilities of reservoir construction.				
Distance of the nearest locality is six (6) times important than possibilities of reservoir construction.				
Head is seven (7) times important than possibilities of reservoir construction.				
	Head	Slope	Distance	Possibilities of reservoir construction
Head	1	2/1	4/1	7/1
Slope	1/2	1	3/1	5/1
Distance	1/4	1/3	1	6/1
Possibilities	1/7	1/5	1/6	1

Table 3.3. (Arrangement of Criteria with Importance W.R.T Efficiency)

3.5	0.4295
2.375	0.2915
1.895	0.2325
0.3773	0.0430
Total = 8.1473	After normalizing.

Importance of criterias with respect to loss				
Head is two (2) times important than slope.				
Slope is three (3) times important than possibilities of reservoir construction.				
Head is four (4) times important than possibilities of reservoir construction.				
Slope is five (5) times important than distance.				
Possibilities of reservoir construction is six (6) times important than distance.				
Head is seven (7) times important than distance.				
	Head	Slope	Distance	Possibilities of reservoir construction
Head	1	2/1	7/1	6/1
Slope	½	1	5/1	3/1
Distance	1/7	1/5	1	1/6
Possibilities of reservoir construction	1/6	1/3	6/1	1

Table 3.4. (Arrangement of Criteria with Importance W.R.T Loss)

3.75	0.4476
2.375	0.2835
0.3773	0.0450
1.874	0.2237
Total = 8.3763	After normalizing.

Importance of criterias with respect to cost				
Distance is two (2) times important than slope.				
Slope is three (3) times important than head.				
Distance is four (4) times important than head.				
Slope is five (5) times important than possibilities of reservoir construction.				
Head is six (6) times important than possibilities of reservoir construction.				
Distance is seven (7) times important than possibilities of reservoir construction.				
	Head	Slope	Distance	Possibilities of reservoir construction
Head	1	1/3	1/4	6/1
Slope	3/1	1	1/2	5/1
Distance	4/1	2/1	1	7/1
Possibilities of reservoir construction	1/6	1/5	1/7	1

Figure 3.5. (Arrangement of Criteria with Importance W.R.T Cost)

1.895	0.2325
2.375	0.2915
3.5	0.4295
0.3773	0.0463
Total = 8.1473	After normalizing.

	Design	Efficiency	Loss	Cost	Row wise sum
Available haed	0.0430×0.232	0.4295×0.430	0.4476×0.046	0.2325×0.291	= 0.2826
Slop	0.2915×0.232	0.2915×0.430	0.2835×0.046	0.2915×0.291	= 0.2953
Distance of nearby locality	0.2325×0.232	0.2325×0.430	0.0450×0.046	0.4295×0.291	= 0.2807
Possibilities of upper reservoir construction	0.4295×0.232	0.0430×0.430	0.2237×0.046	0.0463×0.291	= 0.1416

Now it is clear from final AHP results that slop is the most important criteria & possibilities of dam construction is least important criteria. The importance has been represented bellow:

Slop of the location >Available head > Distance of nearby locality from generating station > possibilities of upper reservoir construction. So, it is clear that loacation-1, West Kalajhari hill of Tripura is most suitable location for pump storage hydro-power plant set up.

5. Cost Effective Analysis

Micro hydro Plant of generating capacity 10-15 MW	
Available head	80 m
Penstock length	100 m
Upper reservoir area	400 sq.m
Upper reservoir volume	1460 m^3 with reservoir wall height 3.65 m
Lower reservoir	Raima river for location-2 & Gomati for 1.

There are various types of costs which are associated with pump storage plant set up. They are:

Various costs associated with pump storage hydro power plant	
Name of cost	Components of costs
Equipment cost	Turbine, generator, transformer, transmission line, transmitting towers, penstock & others accessories equipments.
Installation cost	Costs of concretes, bricks, sand, rods, transportation & labors.

The above mentioned points for these two locations have been listed out & analyzed in this reports. The analysis has been done by site visit & experts opinions (opinions of contractors, engineers, labors, caring center etc.) of respective fields.

Various Costs of Location 1. (West Kalajhari Hill)

Equipment cost	
Name of equipment	Cost
Turbine	Rs. 3862520 (Kaplan turbine with head =80 m & discharge 5-10 m^3/s)
Generator	Rs. 11880000 (10-12 MW)
Transformer	Rs. 510080 (250 V, 50 Hz step down)
Transmission of 4.6 Km main AC	Rs. 12130977 (over head wire) + Rs. 207959 (HV connectors) + Rs. 1109117 (Insulating strings) + Rs. 1500000 (electric tower) + Rs. 500000 (others)
Penstock	Rs. 2500000 (length= 100 m & diameter =0.33 m)
Other equipments	Rs. 500000-600000
Total cost	**Rs. 39700653 (Approx)**

Installation cost		
Type of cost	Quantity	Cost
Cement	2500 packet	Rs. 875000 (Rs. 350 each)
Concrete & stone	4000 sq.feet	Rs. 460000 (Rs. 115 /

		sq.feet)
Brick	50000	Rs. 475000 (Rs. 9.5/ each)
Sand	40 truck	Rs. 144000 (Rs. 3600/ truck)
Rod	50 pitch (16 mm), 75 pitch (10 mm), 60 pitch (8 mm) & 70 pitch (6 mm).	Rs. 59950 (Rs. 1199/pitch) Rs. 35850 (Rs. 478/ pitch) Rs. 18300 (Rs. 305/ pitch) Rs. 13230 (Rs. 189/ pitch)
Transportation		Rs. 1000000-1500000
Material handling		Rs. 10000000
Labor cost		Rs. 4000000
Total cost		**Rs. 18781330 (Approx)**

Various costs of location 2. (Atharomura Hill)

Equipment cost	
Name of equipment	Cost
Turbine	Rs. 3862520 (Kaplan turbine with head =80 m & discharge 5-10 m^3/s)
Generator	Rs. 11880000 (10-12 MW)
Transformer	Rs. 510080 (250 V, 50 Hz step down)
Transmission of 4.6 Km main AC	Rs. 21130750 (over head wire) + Rs. 396900 (HV connectors) + Rs. 2009206 (Insulating strings) + Rs. 1500000 (electric tower) + Rs. 500000 (others)
Penstock	Rs. 2500000 (length= 100 m & diameter =0.33 m)
Other equipments	Rs. 500000-600000
Total cost	**Rs. 44889456 (Approx)**

Installation cost		
Type of cost	Quantity	Cost
Cement	2500 packet	Rs. 875000 (Rs. 350 each)
Concrete & stone	4000 sq.feet	Rs. 472000 (Rs. 118 / sq.feet)
Brick	50000	Rs. 500000 (Rs. 10/ each)
Sand	40 truck	Rs. 152000 (Rs. 3800/ truck)
Rod	50 pitch (16 mm), 75 pitch (10 mm), 60 pitch (8 mm) & 70 pitch (6 mm).	Rs. 60000 (Rs. 1200/pitch) Rs. 35925 (Rs. 479/ pitch) Rs. 18300 (Rs. 305/ pitch) Rs. 13230 (Rs. 189/ pitch)
Transportation		Rs. 1500000-2000000
Material handling		Rs. 15000000
Labor cost		Rs. 4000000
Total cost		**Rs. 23126455 (Approx)**

Location	**Equipment cost**	**Installation cost**	**Total cost**
Location-1	Rs. 39700653	Rs. 18781330	Rs. 58481983
Location-2	Rs. 44889456	Rs. 23126455	Rs. 68015911

Approximate Generation (Using Available Data)

The velocity of water at the penstock entrance (U) = $\sqrt{(2\times 9.8\times 3.4)}$ = 8.16 m/sec.

Frictional head loss through pipe (h_f) = $fLV^2/2gd$= $(0.018\times100\times8.16^2)/(2\times9.8\times0.335)$ = 18.25 m.

Head losses in enlargement & contraction = 2.37 m.

Neat head of power generation = (80-20.62) =59.38 m.

The approximate power available from falling water can be expressed as

$P_{th} = \rho\ q\ g\ h$ (1)

where

P_{th} = power theoretically available (W)

ρ = density (kg/m^3) (~ 1000 kg/m^3 for water)

q = water flow (m^3/s) = 20 m^3/s

g = acceleration of gravity (9.81 m/s^2)

h = Neat height, head (m) = 59.38 m.

P_{th} = 11.65 MW.

Now, the generation cost of 1 KWh electricity charge:

Location	**Total Cost**	**Generation (KWh)**	**Cost/1KWh**
Location-1	Rs. 58481983	11.65×1000×3600 = 41940000	Rs. 1.394
Location-2	Rs. 68015911	11.65×1000×3600 = 41940000	Rs. 1.621

Domestic Electricity Cost in Tripura			
Type of Customer	Selling Price of 1 KWh	Selling price : Cost price **(Lacation-1)**	Selling price : Cost pricice (Location-2)
Load- 120 W	Rs. 1.60	1.15	0.98
Load-250 W	Rs. 1.70	1.22	1.04
Load-250 -500 W	Rs. 1.90	1.36	1.17
Load- 500- 750 W	Rs. 2.10	1.51	1.29
Load- 750- 1000 W	Rs. 2.30	1.65	1.41
Load- 1000- 1500 W	Rs. 2.50	1.79	1.54
Load- 1500-2000 (3-Phase)	Rs. 2.80	2.01	1.72
Load- 2000-5000 W (3- Phase)	Rs. 3.00	2.15	1.85
Load- Above 5000 W	Rs. 3.10	2.23	1.91

Commercial Electricity Cost in Tripura			
Type of Customer	Selling Price of 1 KWh	Selling price : Cost price **(Lacation-1)**	Selling price : Cost price (Location-2)
Load- 300 W	Rs. 2.30	1.78	1.41
Load-300-500 W	Rs. 2.60	1.87	1.60
Load-500 -1000 W	Rs. 3.00	2.15	1.85
Load- 1000- 2000 W	Rs. 3.30	2.37	2.03
Load- 2000- 5000 W (3- Phase)	Rs. 3.80	2.73	2.34
Load- Above 5000 W (3-Phase)	Rs. 4.10	2.94	2.53
Load- Above 2000 (3-Phase)	Rs. 3.80	2.73	2.34

In all cases the ratio of selling price to cost price are greater than 1 & comparatively more in case of location-1 than location-2. Hence from scenario & cost effective analysis, it is clear that location-1 is the best place to set a small hydro-pump storage station in Tripura.

6. Plant Circuit Optimization using Flex-Sim Software

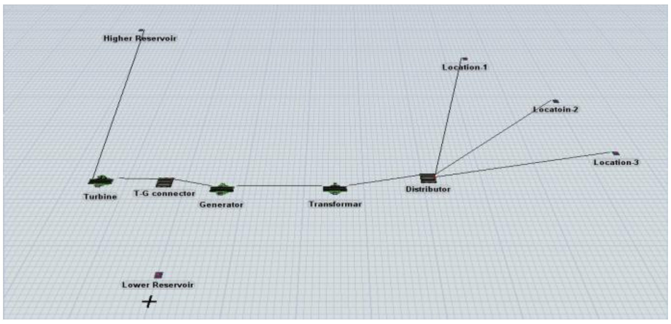


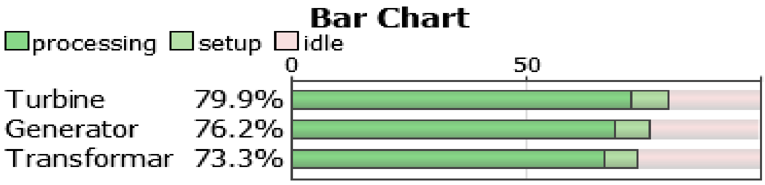
Figure (Plant Layout in Flex-Sim during Generation)

Flexsim Summary Report		
For Generating Stage		
Time:	300	

Object	Class	stats_output	stats_staytimemin	stats_staytimemax	stats_staytimeavg	state_current	state_since
Higher Reservoir	Source	22	0	10.2297	3.6465	4	299.57
Turbine	Processor	21	11	11	11	2	292.323
Generator	Processor	20	11	11	11	2	292.323
Transformar	Processor	20	11	11	11	1	295.209
T-G connector	Queue	21	0	0	0	6	291.323

Distributor	Queue	20	0	0	0	6	295.209
Lower Reservoir	Sink	0	0	0	0	7	0
Location-1	Sink	0	0	0	0	7	0
Locatoin-2	Sink	0	0	0	0	7	0
Location-3	Sink	0	0	0	0	7	0

Output Efficiency Given By Software:



7. Conclusion

Hydro-power is a clean source of energy. It does not cause any type of pollution during production. In case of Tripura the present status is very bad. In this work an integrated approach has been given to find various problems and alternative solutions related to hydro-power generation in this state. To overcome the difficulties due year round shortage of water, concentration has been given in Pump Storage plant. Considering all design alternatives & criteria best location has been selected in the state. Approximate generating output is estimated & cost effective analysis, plant circuit optimization also done. The work implies the possibilities of Small-hydro power plant set up in this state using pump storage technique.

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